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Prospective surveillance for invasive *Staphylococcus aureus* and group A Streptococcus infections in a setting with high community burden of scabies and impetigo

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ABSTRACT

Background: Invasive *Staphylococcus aureus* (iSA) and group A Streptococcus (iGAS) impose significant health burdens globally. Both bacteria commonly cause skin and soft tissue infections (SSTIs), which can result in invasive disease. Understanding of the incidence of iSA and iGAS remains limited in settings with a high SSTI burden.

Methods: Prospective surveillance for admissions with iSA or iGAS was conducted at the referral hospital in Fiji's Northern Division over 48 weeks between July 2018 and June 2019.

Results: There were 55 admissions for iSA and 15 admissions for iGAS (incidence 45.2 and 12.3 per 100,000 person-years, respectively). The highest incidence was found in patients aged ≥65 years (59.6 per 100,000 person-years for iSA and iGAS). The incidence of iSA was higher in indigenous Fijians (iTaukei) (71.1 per 100,000 person-years) compared with other ethnicities (incidence rate ratio 9.7, 95% confidence interval 3.5–36.9). SSTIs were found in the majority of cases of iSA (75%) and iGAS (53.3%). Thirteen of the 14 iGAS strains isolated belonged to *emm* cluster D ($n = 5$) or E ($n = 8$). The case fatality rate was high for both iSA (10.9%) and iGAS (33.3%).

Conclusions: The incidence of iSA and iGAS in Fiji is very high. SSTIs are common clinical foci for both iSA and iGAS. Both iSA and iGAS carry a substantial risk of death. Improved control strategies are needed to reduce the burden of iSA and iGAS in Fiji.

Introduction

Staphylococcus aureus and group A Streptococcus (GAS) are pyogenic Gram-positive bacteria and the most common causes of impetigo and other skin and soft tissue infections (SSTIs) (Steer et al., 2009b). Both *S. aureus* and GAS can lead to invasive disease, imposing considerable health burdens globally (Schuchat et al., 2001). These diseases are recognized as important causes of global morbidity and mortality with case fatality rates (CFRs) of 15–50% for invasive *S. aureus* (iSA) (Tong et al., 2015) and 8–32% for invasive group A Streptococcus (iGAS) (Sanyahumbi et al., 2016). However, detailed understanding of their epidemiology and clinical impact in low- and middle-income countries remains limited.

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In Fiji, an upper-middle-income country, SSTIs are highly prevalent in the community, most commonly manifesting as impetigo, with national prevalence reported at 19.6% in 2007 (Romani et al., 2015a). The majority of impetigo cases in Fiji are caused by *S. aureus* and GAS. Scabies has been shown to be a major driver of impetigo in Fiji (Romani et al., 2015a, 2015b)

S. aureus is the most common cause of bacteraemia; infective endocarditis; and cutaneous, osteoarticular and pleuropulmonary infections globally (Tong et al., 2015). *S. aureus* bacteraemia is the most commonly measured form of iSA. The incidence and CFR of iSA vary widely, depending on differences in geographic setting, health systems, socio-economic status and ethnicity (Tong et al., 2015).

GAS causes a wide spectrum of clinical manifestations, from impetigo and pharyngitis, to life-threatening invasive infection and postinfectious sequelae such as glomerulonephritis and rheumatic fever (Sanyahumbi et al., 2016). IGAS is estimated to occur in 660,000 people globally every year, causing 163,000 deaths (Carapetis et al., 2005). Both pathogens can potentially cause toxic shock syndrome, characterized by rash, profound shock and very high mortality (Steer et al., 2012).

Prospective surveillance was established for iSA and iGAS in the Northern Division of Fiji to determine the baseline burden of these diseases in the context of a larger trial ('Big SHIFT', Trial ID: ACTRN12618000461291), which aims to measure the impact of ivermectin-based mass drug administration on downstream complications of scabies, including iSA and iGAS.

Methods

Setting

Fiji is a South Pacific nation (population 884,887 in 2017) consisting of two main ethnicities: iTaukei or indigenous Fijian (56.8%) and Fijians of Indian Descent (37.5%) (Fiji Islands Bureau of Statistics, 2018). Fiji was ranked 98 of 187 on the United Nations Human Development Index in 2019, placing it in the high human development category, although 28.1% of the population lives below the national basic needs poverty line, defined as a weekly income of 55.12 and 49.50 Fijian Dollars per adult in urban and rural settings, respectively (Fiji Islands Bureau of Statistics, 2015). This study was set in the Northern Division of Fiji (population 131,914) which contains four administrative subdivisions. Surveillance was conducted at the division's referral hospital, Labasa Hospital, located in Macuata subdivision. Labasa Hospital is the only facility in the Northern Division with a microbiology laboratory, intensive care unit (ICU), and general medical and surgical services.

Case definitions and surveillance

A case of iSA or iGAS was defined as a patient with laboratory-confirmed isolation of *S. aureus* or GAS from a usually sterile body site (blood, cerebrospinal fluid, pleural fluid, fascia, bone, solid organ, peritoneal fluid and synovial fluid) on presentation or during admission (Steer et al., 2009a; Jenney et al., 2014). Clinicians routinely obtain blood cultures for patients who are febrile on presentation (temperature >38 °C). More specific sampling is performed when clinical foci are apparent.

This study included patients of all ages admitted to Labasa Hospital with iSA or iGAS. Patients were recruited prospectively from 16 July 2018 to 30 June 2019, with a 2-week pause from 24 December 2018 to 6 January 2019 (total 48 weeks). Study nurses reviewed results from the hospital's microbiology laboratory and ward registers daily, and consulted with nursing and medical staff on the inpatient wards to identify cases for recruitment. Entries made to laboratory records and ward registers over the weekend were reviewed each Monday. Data were collected on patient demographics, clinical site of infection, comorbidities, culture results, management and outcomes. The presence of non-invasive SSTIs, such as cellulitis and abscesses, as diagnosed by the treating clinician was recorded. Comorbidities recorded were: type 2 diabetes mellitus, immunosuppression, heart disease, renal disease, liver disease, malignancy and chickenpox. The REDCap Mobile App (Vanderbilt University, TN, USA) was used to record data, and these were subsequently uploaded on to a secure online server hosted by Murdoch Children's Research Institute (Harris et al., 2009).

Laboratory methods

Labasa Hospital houses the only microbiology laboratory in the Northern Division. *S. aureus* and GAS were identified using Gram staining and catalase testing. Other confirmatory tests included plate DNAse testing (for *S. aureus*) and streptococcal latex agglutination and bacitracin susceptibility (for GAS). Antibiotic susceptibility testing was undertaken using the disk diffusion methods of the Clinical and Laboratory Standards Institute. GAS isolates from a sterile site were stored at −20 °C at Labasa Hospital and transported to the laboratory at Murdoch Children's Research Institute, where *emm* typing and *emm* cluster typing were performed using published procedures (Sanderson-Smith et al., 2014; Centers for Disease Control and Prevention, 2018a).

Statistical calculations

Incidence was calculated using the population of the Northern Division from the 2017 Fiji Bureau of Statistics census (n = 131,914) (Fiji Islands Bureau of Statistics, 2018). As ethnicity breakdowns were unavailable from the 2017 census, denominators for ethnicity were calculated by applying Northern-Division-specific ethnicity proportions from the 2007 census to the 2017 census population. Comparisons for incidence between ethnicities were performed between the iTaukei population and other ethnicities, including Fijians of Indian Descent and other minorities. The estimated number of people with diabetes in the Northern Division was 22,991, derived by applying age-adjusted proportions from a 2011 national survey to the 2017 census population (Fiji Ministry of Health and Medical Services and World Health Organization, 2011). The incidence rate ratio (IRR) was calculated to allow comparisons between different groups. Stata Version 15.1 (StataCorp, College Station, TX, USA) was used for statistical calculations.

Ethical considerations

Ethical approval was granted by the Fiji National Health Research Ethics Review Committee (Reference No. 2018.38.NOR) and the Royal Children's Hospital Human Research Ethics Committee in Melbourne, Australia (Reference No. 38020). All participants (or legal guardian if participant was aged <18 years) provided written consent to be enrolled in the study. Additional written consent was obtained for typing of GAS isolates. Where no informed consent was obtained, the case was noted for incidence calculations and outcomes alone.

Results

Incidence

During the 48-week surveillance period, there were 55 admissions with iSA and 15 admissions with iGAS, equivalent to incidence rates of 45.2 per 100,000 person-years [95% confidence

interval (CI) 34.0–58.8] and 12.3 per 100,000 person-years (95% CI 6.9–20.3), respectively. Of these cases, one had both iSA and iGAS (combined total of 69 admissions, incidence 56.7 per 100,000 person-years, 95% CI 44.1–71.7). Informed consent to collect clinical and demographic data was obtained for 52 (94.5%) of the iSA cases and all iGAS cases.

The incidence rates of iSA and iGAS were higher in the iTaukei population compared with other ethnicities (IRR 9.7, 95% CI 3.5–36.9 for iSA; IRR 3.2, 95% CI 0.9–17.8 for iGAS; Table 1). There was no significant difference in incidence between males and females for either iSA or iGAS (IRR 1.7, 95% CI 0.9–3.1 for iSA; 0.8, 95% CI 0.3–2.6 for iGAS; Table 1). High incidence of iSA and iGAS was observed

Table 1
Number and incidence of invasive infections caused by *Staphylococcus aureus* and group A Streptococcus by sex, ethnicity, age group and type 2 diabetes status.

	Staphylococcus aureus	Group A Streptococcus	Combined
Male			
n (%)	33 (63.5)	7 (46.7)	40 (60.6)
Incidence (95% CI)	53.0 (36.4–74.4)	13.5 (5.8–26.5)	64.2 (45.9–87.4)
IRR	1.7 (0.9–3.1)	0.8 (0.3–2.6)	1.4 (0.9–2.5)
Female			
n (%)	19 (36.5)	8 (53.3)	26 (39.4)
Incidence (95% CI)	32.0 (19.3–49.9)	13.5 (5.8–26.5)	43.7 (28.6–64.1)
IRR	Ref	Ref	Ref
iTaukei			
n (%)	48 (92.3)	12 (80.0)	59 (89.4)
Incidence (95% CI)	71.1 (52.4–94.3)	17.8 (9.2–31.1)	87.4 (66.5–112.8)
IRR	9.7 (3.5–36.9)	3.2 (0.9–17.8)	6.8 (3.1–17.6)
Other ethnicity			
n (%)	4 (7.7)	3 (20.0)	7 (10.6)
Incidence (95% CI)	7.4 (2.0–18.9)	5.5 (1.1–16.2)	12.9 (5.2–26.6)
IRR	Ref	Ref	Ref
0–4 years			
n (%)	8 (15.4)	2 (13.3)	10 (15.2)
Incidence (95% CI)	59.6 (25.7–117.3)	14.9 (1.8–53.9)	74.5 (35.7–136.9)
IRR	0.9 (0.3–3.4)	0.2 (0.02–1.3)	0.6 (0.2–1.7)
5–14 years			
n (%)	14 (26.9)	1 (6.7)	15 (22.7)
Incidence (95% CI)	55.3 (30.2–92.8)	4.0 (0.1–22.0)	59.3 (33.2–97.7)
IRR	0.8 (0.3–2.9)	0.1 (0.001–0.5)	0.5 (0.2–1.3)
15–24 years			
n (%)	8 (15.4)	0	8 (12.1)
Incidence (95% CI)	43.5 (18.8–86.0)	–	43.5 (18.8–86.0)
IRR	0.6 (0.2–2.5)	–	0.4 (0.1–1.0)
25–34 years			
n (%)	2 (3.8)	0	2 (3.0)
Incidence (95% CI)	11.9 (1.4–43.0)	–	11.9 (1.4–43.0)
IRR	0.2 (0.02–1.1)	–	0.1 (0.01–0.5)
35–44 years			
n (%)	3 (5.8)	2 (13.3)	5 (7.6)
Incidence (95% CI)	18.7 (3.9–54.8)	12.5 (1.5–45.1)	11.9 (1.4–43.0)
IRR	0.3 (0.04–1.4)	0.2 (0.02–1.1)	0.3 (0.07–0.8)
45–54 years			
n (%)	7 (13.5)	2 (13.3)	9 (13.6)
Incidence (95% CI)	49.2 (19.8–101.4)	14.1 (1.7–50.8)	6.3 (28.9–120.1)
IRR	0.7 (0.2–2.9)	0.2 (0.02–1.3)	0.5 (0.2–1.5)
55–64 years			
n (%)	5 (9.6)	3 (20.0)	8 (12.1)
Incidence (95% CI)	48.9 (15.9–114.1)	29.3 (6.1–85.7)	78.2 (33.8–154.1)
IRR	0.7 (0.2–3.1)	0.4 (0.07–2.2)	0.6 (0.2–1.9)
≥65 years			
n (%)	5 (9.6)	5 (33.3)	9 (13.6)
Incidence (95% CI)	67.9 (22.1–158.4)	67.9 (22.1–158.4)	122.2 (55.9–231.9)
IRR	Ref	Ref	Ref
With diabetes			
n (%)	14 (23.9)	7 (46.7)	20 (3.3)
Incidence (95% CI)	66 (36.1–110.7)	33 (13.3–67.8)	94.24 (57.57–145.51)
IRR	1.7 (0.9–3.3)	4.1 (1.3–13.1)	2.1 (1.2–3.6)
Without diabetes			
n (%)	38 (73.1)	8 (53.3)	46 (69.7)
Incidence (95% CI)	37.8 (26.8–51.9)	8 (3.4–15.7)	45.75 (33.5–61.0)
IRR	Ref	Ref	Ref
Total			
n	52	15	66
Incidence (95% CI)	45.2 (34.0–58.8)	12.3 (6.9–20.3)	56.7 (44.1–71.7)

CI, confidence interval; Ref, reference group; IRR, incidence rate ratio.
Incidence is expressed as per 100,000 person-years.
Demographic groups without an IRR listed were the reference group for their respective category. IRR was not calculated for groups with zero cases.

in very young patients and elderly patients, with peak combined incidence observed in patients aged ≥65 years (122.2 per 100,000 person-years; IRR 10.3, 95% CI 2.1–97.7 compared with patients aged 25–34 years; Figure 1).

A large proportion of cases [33 iSA (63.5%) and seven iGAS (46.7%)] were referred from facilities outside Labasa Hospital. Nineteen (36.5%) iSA cases and eight (53.3%) iGAS cases originated from within Macuata subdivision, equivalent to subdivision-specific incidence rates of 31.2 per 100,000 person-years (95% CI 18.8–48.7) and 13.3 per 100,000 person-years (95% CI 5.7–25.9), respectively. There were significant variations in the incidence of iSA and iGAS cases originating from the four subdivisions (Table S1, see online supplementary material).

Clinical characteristics

Nearly all patients had an overt clinical focus of infection; bacteraemia without focus was only observed in one case of iSA. SSTIs were the most common clinical focus of infection, observed in 75% and 53.3% of iSA and iGAS cases, respectively (Figure 2). There were no cases of infective endocarditis or toxic shock syndrome. Most patients had bacteraemia: 48 cases of iSA (92.3%) and eight cases of iGAS (53.3%). The all-age incidence rates of *S. aureus* bacteraemia and GAS bacteraemia were 39.4 and 6.6 per 100,000 person-years, respectively (Table S2, see online supplementary material).

Diabetes was noted in 26.9% and 46.7% of patients with iSA and iGAS, respectively. The incidence of iSA among patients with diabetes was 66.0 per 100,000 person-years, compared with 37.8 per 100,000 person-years in patients without diabetes (IRR 1.8, 95% CI 0.9–3.3). The incidence of iGAS among patients with diabetes was 33 per 100,000 person-years compared with 8 per 100,000 person-years in patients without diabetes (IRR 4.1, 95% CI 1.3–13.1; Table 1). Higher incidence of iSA and iGAS in patients with diabetes was found in all age groups ≥45 years (Table S3, see online supplementary material). All other comorbidities were not common.

Blood was the most common sterile site from which positive cultures were isolated (n = 56, 84.8%), followed by deep tissue swabs (n = 14, 21.2%) and synovial fluid (n = 9, 13.6%) for both iSA and iGAS combined (Table 2). Methicillin-resistant *S. aureus* was isolated from one patient. The total number of samples collected from each sterile site and proportion that was positive for *S. aureus* and GAS are outlined in Table S4 (see online supplementary material).

Molecular epidemiology

emm typing and *emm* cluster typing were performed on samples obtained from 14 of 15 cases with iGAS. The most common *emm* type was *emm*65.4, isolated in three cases (Table 3). All isolates except one belonged to *emm* cluster D (n = 5) or E (n = 8).

Management

Five patients (9.6%) with iSA and two patients (13.3%) with iGAS were admitted to the ICU. Paediatric cases were over-represented: four of five patients with iSA were aged <8 years, and one of the patients with iGAS was 2 years old.

Forty-one patients (78.9%) with iSA and nine patients (60%) with iGAS required surgery in the operating theatre, some on repeated occasions. The most common procedures were soft tissue incision and drainage (17 cases, 32.7%), soft tissue debridement (13 cases, 25.0%) and joint washout (12 cases, 23.1%) for iSA, and soft tissue debridement for iGAS (five cases, 33.3%, Table S5, see online supplementary material).

The median duration of intravenous antibiotics was 14 days [interquartile range (IQR) 7–16.5 days] for iSA and 10.5 days (IQR 8–20 days) for iGAS, with duration varying slightly by clinical focus (Table S6, see online supplementary material). The median length of stay in hospital was 15 days for both iSA (IQR 8–18, range 2–56 days) and iGAS (IQR 8–23, range 3–63 days).

Outcomes

Overall CFR was high. Including all 66 admissions with iSA and iGAS, 10 (14.5%) resulted in death, nine of whom were participants in the study. One of the deaths was the patient with both iSA and iGAS. There were six deaths (CFR 10.9%) among cases with iSA and five deaths (CFR 33.3%) among cases with iGAS. Among the nine participants who died, eight (88.9%) were of iTaukei ethnicity. A higher CFR was observed among patients aged ≥55 years (47.1%) compared with those aged <55 years [2%, IRR 23.1, 95% CI 3.1–1023.2; Table S5 (see online supplementary material)]. Patients with diabetes also had a higher CFR compared with patients

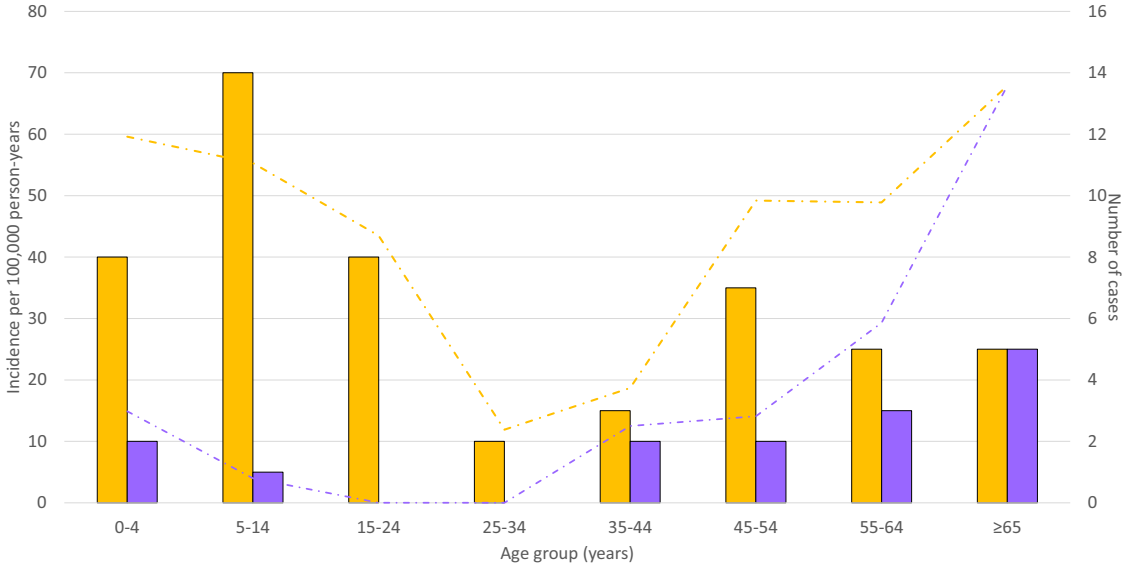

Figure 1. Age-specific incidence of invasive infections by *Staphylococcus aureus* and group A Streptococcus in the Northern Division of Fiji, 15 July 2018–30 June 2019. Orange line, incidence of invasive *Staphylococcus aureus*; purple line, incidence of invasive group A Streptococcus; orange bars, number of invasive *Staphylococcus aureus* cases; purple bars, number of invasive group A Streptococcus cases.

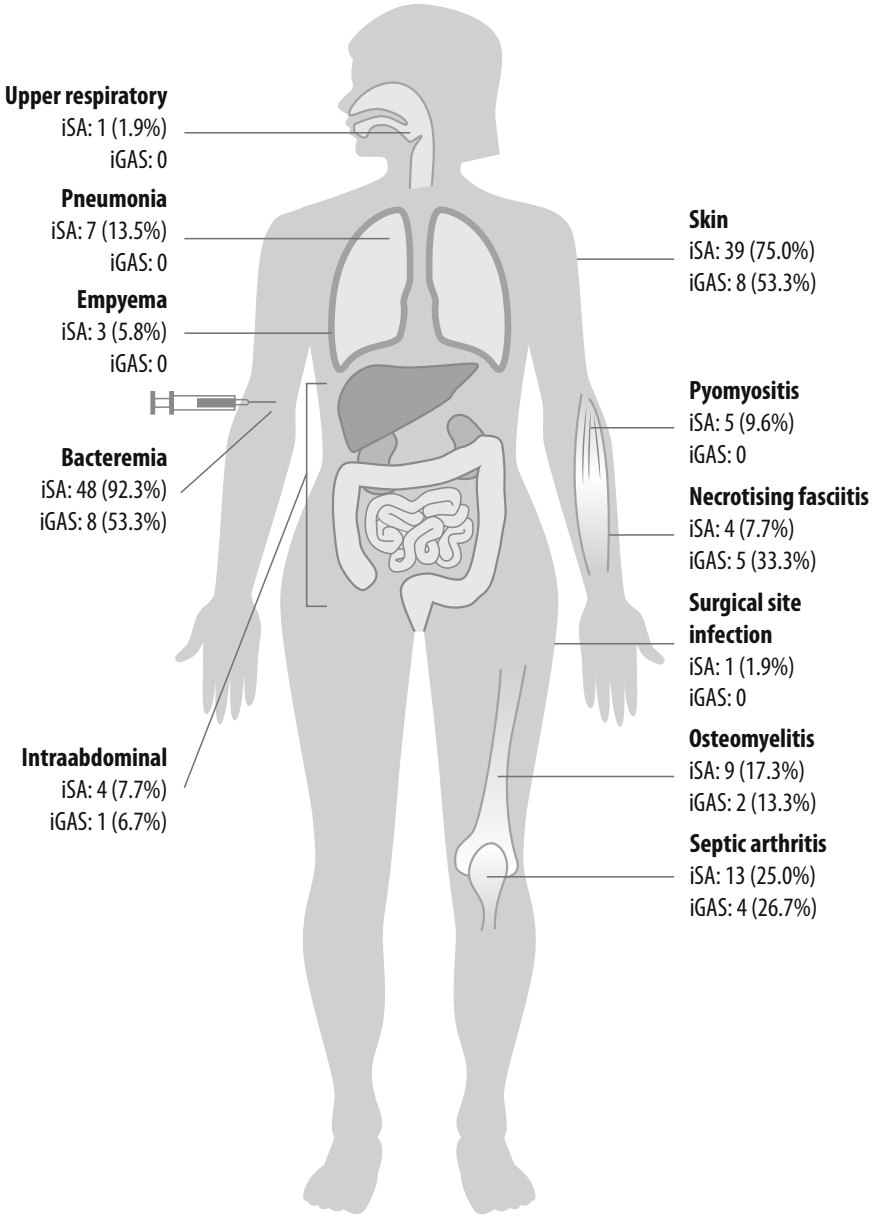

Figure 2. Clinical sites of infection for, invasive *Staphylococcus aureus*; iGAS, invasive group A Streptococcus.

without diabetes [IRR 8.1, 95% CI 1.5–79.4; Table S7 (see online supplementary material)].

Discussion

iSA and iGAS had a high disease burden in Fiji, with little change from comparable studies performed at the Colonial War Memorial Hospital (the national referral centre) in 2007 (Steer et al., 2009a; Jenney et al., 2014). The present data highlight that SSTIs are common foci for both iSA and iGAS. Both iSA and iGAS carry a substantial risk of death, especially iGAS with a CFR of 33%.

The incidence rates of iSA (45.2 per 100,000 person years) and iGAS (12.3 per 100,000 person years) in this population were substantially higher compared with those documented in high-income settings. Studies from North America, urban Australia and Scandinavia have reported rates of iSA between 19.0 and 33.7 per 100,000 person-years and iGAS between 3.8 and 7.6 cases per 100,000 person-years (Laupland et al., 2013; Nelson et al., 2016; Centers for Disease Control and Prevention, 2018b). In contrast, a similar epidemiologic situation appears to exist in neighbouring Pacific communities. Studies in New Caledonia have reported a very high incidence of iGAS (between 38 and 43 per 100,000 person-years), and observed that a high proportion of cases had an SSTI focus (Le Hello et al., 2010; Baroux et al., 2014).

The incidence of disease was six times higher in the iTaukei population compared with people of other ethnicities in Fiji. iTaukei Fijians also appear to have higher risk of SSTIs, other GAS diseases (including rheumatic heart disease) (Romani et al., 2015a; Engelman et al., 2016) and other Gram-positive infections, including pneumococcal pneumonia (Magree et al., 2005). The reason for this is unclear. Disparities in the incidence of iSA and iGAS have been noted between ethnicities in other populations. In New Zealand, Maori and Pacific Islanders have 10 times higher incidence of iSA compared with the non-Maori/non-Pacific population (Vogel et al., 2020), and Pacific Islanders had seven-fold higher incidence of iGAS than the European population (Williamson et al., 2015). Similar disparities in the incidence of iSA and iGAS have been described between indigenous and non-

Table 2
Sites of invasive isolates for invasive *Staphylococcus aureus* (iSA) and group A streptococcal (iGAS) infections.

Culture-positive site	iSA, *n* = 52 *n* (%)	iGAS, *n* = 15 *n* (%)	Total, *n* = 66 *n* (%)
Blood	48 (92.3)	8 (53.3)	56 (84.8)
Deep tissue swab	11 (21.2)	3 (20.0)	14 (21.2)
Bone	4 (7.7)	0	4 (6.1)
Fascia	3 (5.8)	3 (20.0)	6 (9.1)
Muscle	2 (3.8)	0	2 (3.0)
Joint	2 (3.8)	0	2 (3.0)
Synovial fluid	7 (13.5)	3 (20.0)	9 (13.6)
Fluid, other	5 (9.6)	1 (6.7)	6 (9.1)
Pus, empyema	2 (3.8)	0	2 (3.0)
Pus, liver	2 (3.8)	0	2 (3.0)
Pus, kidney	1 (1.9)	0	1 (1.5)
Peritoneal	0	1 (6.7)	1 (1.5)
Bone tissue	1 (1.9)	1 (6.7)	2 (3.0)

Table 3
emm types and *emm* clusters of group A Streptococcus isolated from sterile sites.

Case	Specimen	*emm* type	*emm* cluster
1	Blood	*emm*65.4	E6
2	Blood	*emm*65.4	E6
3	Synovial fluid	*emm*65.4	E6
4	Deep wound swab (necrotizing fasciitis)	*emm*70.0	D4
5	Blood	*emm*71.0	D2
6	Blood and deep wound swab (necrotizing fasciitis)	*emm*73.0	E4
7	Blood	*emm*89.0	E4
8	Blood	*emm*101.0	D4
9	Blood and pus from skin abscess	*emm*104.0	E2
10	Blood	*emm*108.1	D4
11	Blood	*emm*123.0	D3
12	Synovial fluid	*emm*124.0	E4
13	Bone	*emm*232.0	E4
14	Deep wound swab (necrotizing fasciitis)	*emm*238.2	A-C3

indigenous populations in Australia (Norton et al., 2004; Tong et al., 2012). Higher annual incidence of SSTIs presenting to hospital has also been described in Australian Indigenous populations (18.9 per 1000 population) compared with non-Indigenous populations (2.9 per 1000 population) (Harch et al., 2017). The reason for these differences is unclear, but likely relates to a complex interplay between genetic, lifestyle and socio-economic factors (Tong et al., 2012).

A major contributing factor to the high rates of iSA and iGAS in these settings is likely to be the high community burden of SSTIs. This was supported by the finding that SSTIs were the most common clinical focus of infection for both iSA (75%) and iGAS (53.3%) in this study. This was also supported by the finding that almost all iGAS isolates belonged to *emm* types and *emm* clusters that are associated with skin infections (Baroux et al., 2014; Sanderson-Smith et al., 2014). The prevalence of scabies and impetigo are very high in Fiji, especially in the Northern Division, with reported rates of 28.5% and 23.7%, respectively (Romani et al., 2015a). Similarly, Indigenous populations in Australia experience very high rates of iSA and iGAS (Tong et al., 2012; Oliver et al., 2019), and have 6.6 times higher incidence of admissions for SSTIs compared with non-Indigenous populations (Harch et al., 2017).

A number of risk factors for iSA and iGAS were observed in this study. The highest incidence was found in the youngest and oldest age groups, particularly among those aged <5 and ≥65 years. Children comprised 90% of ICU admissions. The CFR was highest in older patients, consistent with other studies (Van Hal et al., 2012; Tong et al., 2015), likely due to the presence of underlying comorbidities, particularly type 2 diabetes which, as demonstrated in this study, resulted in higher incidence of iSA and iGAS and CFRs overall.

The *emm*-type profile observed in this study was diverse, even in this small sample. There was a notable absence of *emm* types classically described among invasive isolates in high-income countries, especially *emm*1 (O'Loughlin et al., 2007). This high diversity, absence of classic *emm* types, and predominance of skin tropic *emm* types and *emm* cluster types is consistent with previous studies of the molecular epidemiology of GAS in Fiji and surrounding Pacific island countries (Steer et al., 2009a; Baroux et al., 2014).

The main limitation of this study was that surveillance was limited to the referral hospital of the Northern Division, therefore providing a minimum estimate of the burden of iSA and iGAS in this population. Furthermore, some of the data on length of stay, treatment received and outcomes may have been incomplete for patients transferred back to their referring hospitals. Another reason that the study results represent a minimum estimate of iSA and iGAS in the study population is that the collection of samples from patients was determined by clinician assessment. It is possible that patients presenting to Labasa Hospital or other facilities in the Northern Division with underlying iSA or iGAS may not have had invasive samples collected, or may have had samples collected after the administration of antibiotics which may reduce the detection of bacteria using standard culture methods.

Despite the huge clinical and public health burden caused by *S. aureus* and GAS, there are no available vaccines against either pathogen, nor are there proven public health strategies to prevent severe infections. In settings such as Fiji, where community prevalence of impetigo is very high, it is plausible that the incidence of invasive disease could be diminished by reducing the burden of impetigo in the community. Multiple studies in the Pacific have shown that mass drug administration for control of scabies results in a marked reduction in the prevalence of impetigo (Romani et al., 2015b; Marks et al., 2020). Determining the effect of such community-based strategies to reduce the prevalence of scabies and impetigo on the incidence of iSA and iGAS would be valuable in guiding health policy for disease prevention.

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Conflict of interest

None declared.

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.ijid.2021.05.041.

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